PITFALL TRAPS FOR ARTHROPODS: AN EVALUATION OF THEIR EFFICIENCY, WITH SPECIAL REFERENCE TO FIELD CRICKETS (GRYLLIDAE: ORTHOPTERA)[1]

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Pitfall trapping, a commonly used technique for sampling arthropods in the field, often involves the use of either poisonous or non-biodegradable chemicals. We explored the possibility of using a non-poisonous, degradable alternative, and edible oil in pitfall traps designed to sample arthropods. Our results showed that a film of edible oil over water is an effective substitute for detergent solution for the capture of insect groups such as crickets, grasshoppers, ants, cockroaches and flies. Only in the case of spiders was detergent found to be significantly more effective than oil. For crickets, we further showed that live trapping without the use of chemicals was a viable alternative to traps with chemicals. Pitfall trapping was, however, inadequate as a method to quantify relative abundance and habitat associations of crickets at the species level.

Key words: Orthoptera, Gryllidae, crickets, grasshoppers, pitfall traps, arthropods, insects, sampling

Pitfall trapping is a widely used technique for sampling surface arthropods such as ants, beetles, cockroaches, spiders and crickets (Southwood 1978). It is simple and inexpensive. A plastic or glass jar with steep sides is placed in a pit dug into the ground, so that the rim of the jar is level with the soil surface. In order to prevent trapped animals from escaping, such traps usually contain an aqueous solution of a chemical such as picric acid, iso-propanol, tri-sodium orthophosphate or a detergent. Traps designed to simultaneously kill and preserve arthropods may contain either formalin or ethylene glycol (Southwood 1978).

The efficiency of a pitfall trap increases with its circumference, and relatively large arthropods require larger traps to be efficiently captured (Luff 1975; Brennan *et al.* 1999). This in turn means increased volume of the chemical per trap. This poses a problem when sampling in remote forested areas or difficult terrain, since these chemical-filled traps must be transported out of the area after sampling: it would be undesirable to simply remove the trapped insects and empty the toxic contents of the trap into the soil. In the first experiment, we explored the possibility of using a non-poisonous, biodegradable substitute such as edible oil instead of detergents or poisonous chemicals in pitfall traps.

In the second experiment, we captured animals live in traps that contained no chemicals or solutions, but were designed to prevent the insects from escaping. Live trapping offers two major advantages over conventional pitfall trapping: the researcher may choose between different methods of killing or preservation. For example, insects collected for molecular studies need to be preserved in 90-95% ethanol, whereas those collected for morphological studies could be killed in cyanide jars and then preserved dry. Live trapping also permits behavioural or mark and recapture studies, and prevents the unnecessary killing of non-target groups including other invertebrates and small vertebrates that fall into the traps. These can be released into the habitat if the traps are frequently monitored.

We evaluated the efficiency of the above traps in capturing surface-dwelling field cricket and ground cricket species, and attempted to examine microhabitat associations and seasonal variations in the relative abundance of cricket species, using this technique.

METHODS

Experiment 1: To compare the trapping efficiency of pitfall traps containing plain water (W), water with a film of oil (O) and water with detergent (D), five sets (blocks) of three traps (each representing one treatment) were laid out in five different microhabitats (tall grass, short grass, mixed grass + forbs, forbs alone, and leaf litter). The experiment was designed to eliminate the possible effect of microhabitat in biasing capture rates and probabilities (Melbourne 1999). The three traps within a block were placed at a distance of 2 m from each other. Each trap consisted of a plastic bowl (21 cm diameter, 7 cm depth) sunk into the ground with the rim at surface level (Fig. 1a). The bowl was filled to about two-thirds of its volume with either plain water (as the control), or water with one ml of oil poured on the surface, or a 2% detergent solution. In this experiment, traps with plain water were used as controls, rather than empty traps, since the relatively small depth of the traps made it very easy for arthropods to crawl or fly out of empty traps. The traps were left open for 15 days and nights, over a period of three months from April-June 2000. All traps were

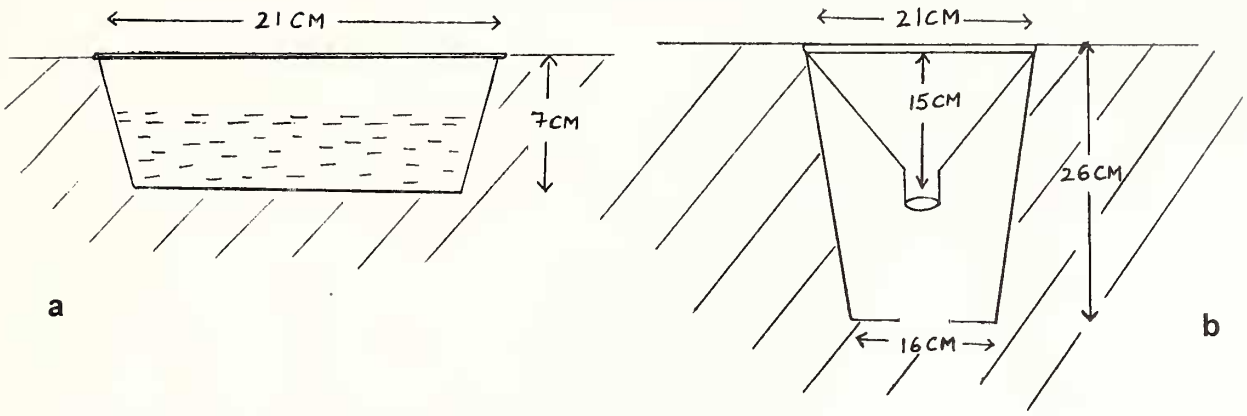

Fig. 1: Schematic illustration of the pitfall traps used in the study; a. Design of the traps used in the first experiment, b. Design of the trap type used in the second experiment

monitored at the end of a 24-hour period of sampling and the number of trapped individuals of different arthropod groups (both nymphs and adults) above one mm in length were counted and then air-dried for preservation.

Experiment 2: 'Live traps' were set up in different microhabitats: leaf litter, tall grass and short grass (less than six cm in height), with four traps per habitat, spaced 7 m apart. Each trap consisted of a deep, cylindrical plastic bucket (21 cm diameter, 26 cm depth) covered by a funnel that fit it exactly: this was sunk into the soil as in the previous experiment (Fig. 1b). A wet sponge and some soil were placed in each trap to keep it moist. During the monsoon, the bottom of the trap was removed to allow percolation of rainwater into the soil, and to prevent the trapped animals from drowning. Traps were monitored every second day for 15 weeks between January and September, during the dry season (January to April) for ten weeks and during the wet season (June to September) for five weeks. In this experiment, we focused only on crickets (Family Gryllidae, Order Orthoptera). The total number of crickets trapped every 48 hours was counted. Adults were identified to the genus or species level (wherever possible) using the taxonomic keys of Chopard (1969).

All experiments were carried out on the campus of the Indian Institute of Science, Bangalore, in non-landscaped areas with natural vegetation.

Data were first subjected to an analysis of variance, followed by *post-hoc* pair-wise comparisons using either *t*-tests (for the first experiment) or Tukey's HSD test (for the second experiment).

RESULTS

Are pitfall traps containing edible oil as effective as those containing detergents?

The mean number of individuals captured per trap (n = 5 traps for each of the three treatments) depended both on the treatment and the particular arthropod taxon being considered (ANOVA: $F = 15.47$, $P < 0.0001$ and $F = 21.9$, $P < 0.0001$ for the main effect of treatment and taxon respectively; $F = 5.52$, $P < 0.001$ for the interaction between them). Interestingly, for ants and cockroaches, traps containing water with a film of oil were far more effective than those containing either water alone or water with detergent (Fig. 2a: the letters a, b and c are used to indicate significant differences at $\alpha = 0.05$, *post-hoc* paired comparison *t*-tests).

For crickets and grasshoppers, traps containing water with oil or with detergent were significantly more effective than those containing water alone (Fig. 2b: symbols mean the same as in 2a. There were no significant differences in mean number captured between traps containing oil or detergent. Spiders, on the other hand, were significantly more likely to be captured in traps containing detergent solution, rather than those containing water with a film of oil, or water alone (Fig. 2b: paired comparison *t*-tests: $P < 0.05$ in each case). Dipterans (represented by flies) were captured in low numbers, but traps with oil or detergent added were significantly more effective than those containing only water (Fig. 2b: $P < 0.05$ in each case).

The mean rates of capture of crickets (defined as the number of individuals captured per trap per day) were 0.09 ±0.06 (water alone), 0.59 ±0.27 (water + oil) and 0.32 ±0.06 (water + detergent) respectively for the three treatments.

The effects of microhabitat, season and developmental status on mean capture rates of crickets using live trapping

The mean rate of capture of live crickets in empty traps in the second experiment was 0.36 ±0.13 individuals per trap per day. Since the capture rate in pitfall traps was low for crickets, we pooled the number of individuals captured per week in the four replicate traps (in each microhabitat) to use as the individual data points for statistical analysis. Analysis

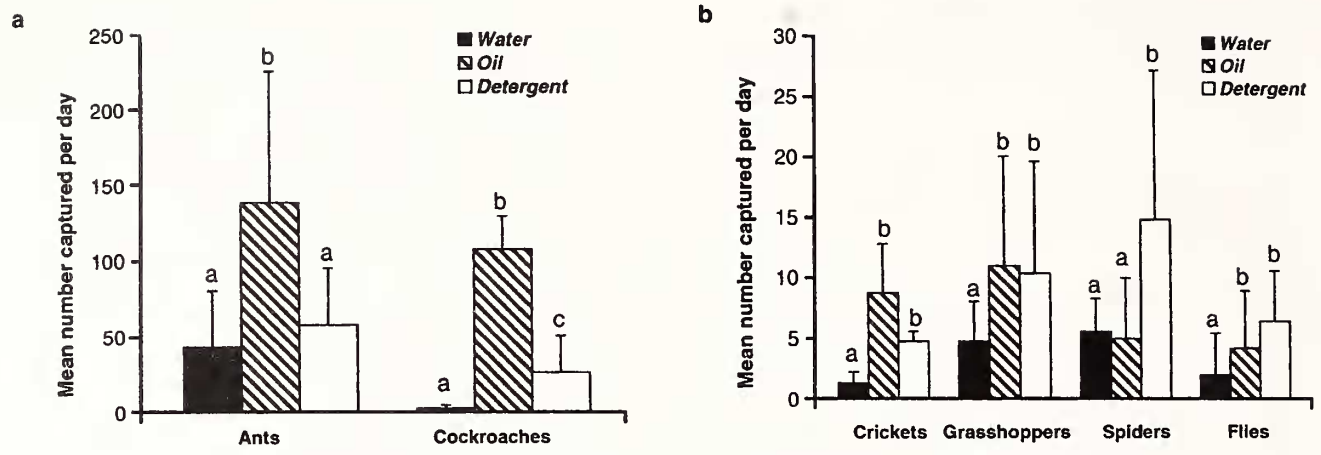

Fig. 2: Comparison of the effectiveness of pitfall traps containing only water, water with a film of oil, and detergent solution in capturing different arthropod taxa. The letters a, b and c above the bars indicate significant differences between treatments ($\alpha = 0.05$) (Note the difference in scale between the two graphs)

of variance was then carried out on these data to test the effects of three factors: microhabitat (leaf litter, tall grass or short grass), season (dry or wet) and developmental stage (nymph or adult) on mean capture rate of crickets. Both developmental status and season had highly significant independent effects ($F = 35.45$, $P < 0.0001$, $F = 22.65$, $P < 0.0001$ respectively), and microhabitat had a marginally significant independent effect, on capture rate ($F = 3.07$, $P = 0.05$). In addition, there were highly significant interactions between the effects of microhabitat and developmental status ($F = 13.17$, $P < 0.0001$), and between microhabitat and season ($F = 8.63$, $P < 0.001$). Significantly more nymphs than adults were captured (when pooled over the seasons) in both leaf litter and tall grass microhabitats, whereas nymphs and adults were trapped in approximately equal (low) numbers in the short grass habitat (Fig. 3a: the letters a and b are used to denote significant differences at the 0.05 level of significance using Tukey's HSD test). In the tall grass and short grass habitats, the mean number of crickets captured per week (pooling nymph and adult numbers) was far higher in the wet season than the dry (Fig. 3b). In the leaf litter habitat, however, the mean numbers captured were approximately the same in both wet and dry season.

Species composition

A total of 15 species of crickets were captured in live traps: 13 species belonging to six genera of the subfamily Gryllinae (field crickets) and two species of the genus *Pteronemobius* (subfamily Nemobiinae or ground crickets) (Table 1). Of the 15 species, ten were found as adults

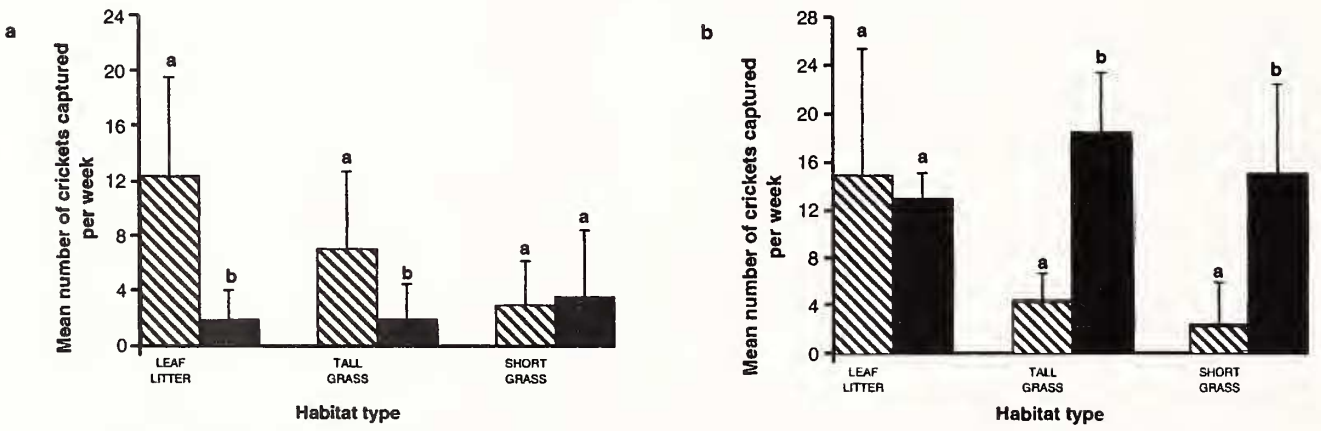

Fig. 3: Capture rates of crickets by live trapping; a: Comparison of capture rates of nymphal instars (hatched bars) and adults (black bars) in three types of micro-habitat. b: Comparison of capture rates of crickets between the dry (hatched bars) and wet (black bars) seasons in three types of micro-habitat. The letters a and b above the bars indicate significant differences between factors ($\alpha = 0.05$)

Table 1: Species composition and abundance of adult crickets captured in three micro-habitats in the dry and wet seasons

			Total number of individuals captured					
			Short grass		Tall grass		Leaf litter	
No.	Genus	Species	Dry	Wet	Dry	Wet	Dry	Wet
1	*Scapsipedus*	*grylloides*		15	1	4	17	8
2	*Loxoblemmus*	*equestris*		1		2		1
3	*Coiblemmus*	*compactus*		7		3		1
4	*Coiblemmus*	unknown				2		
5	*Itaropsis*	*tenellas*			1	1	3	
6	*Gryllopsis*	*maculithorax*		1		2		
7	*Gryllopsis*	*falconneti*		2				
8	*Gryllopsis*	*femorata*		3		2		
9	*Gryllopsis*	*furcata*				1		
10	*Gryllopsis*	unknown				1		
11	*Gryllus*	*fletcheri*				1		
12	*Gryllus*	*guttiventris*	7	6		3		
13	*Gryllus*	*confirmatus*		2				
14	*Pteronemobius*	*csikii*	7				1	
15	*Pteronemobius*	*taprobanensis*		1	3	2		
Total			14	38	5	24	21	10

exclusively in the wet season, one (*Pteronemobius csikii*) only in the dry season, with the other four species being found as adults in both wet and dry seasons. With respect to microhabitat, four species were unique to the tall grass and two to the short grass. Three species, namely *Scapsipedus grylloides*, *Coiblemmus compactus* and *Loxoblemmus equestris* were found in all three microhabitats. Of the remaining six species, five were found in both short and tall grass, whereas one species (*Pteronemobius csikii*) was shared between the leaf litter and short grass habitats.

The low capture rates of crickets precluded a meaningful statistical analysis of relative abundance and microhabitat preferences of species.

DISCUSSION

Our experiments show that the use of poisonous chemicals can be avoided in pitfall trapping of arthropods. A small quantity of edible oil is a good substitute for the more commonly used detergents, and does not compromise the efficiency of capture for insect groups such as crickets, grasshoppers, ants, cockroaches and flies. In fact, the capture rate for cockroaches and ants was much higher in traps containing oil rather than detergents, perhaps because the oil acted as an attractant to these highly chemosensitive animals. The use of both oil and detergent, however, makes mounting and preservation of specimens more difficult.

The efficiency of pitfall trapping has been studied earlier, for the effects on capture rates and probabilities, of features such as the material used, trap size, different chemicals and preservatives, and the frequency of sampling (Luff 1975; Vennila and Rajagopal 1999, 2000). Almost all of these studies have focused on one taxonomic group, the beetles. These studies have revealed that traps made of glass have significantly higher capture efficiencies than either plastic or metal (Luff 1975; Vennila and Rajagopal 2000). In their study of tropical carabid beetles, Vennila and Rajagopal (2000) found no significant differences in capture rates between traps containing different kinds of chemicals or preservatives. In their experiments, empty traps were significantly less effective than those containing chemicals. This may have been because their empty traps were not designed to prevent live insects from escaping.

For one group of insects, the crickets (Suborder Ensifera, Order Orthoptera), we have demonstrated the possibility of live trapping without compromising on capture rates. The mean rate of capture of live crickets in empty traps in the second experiment in our study was comparable with those yielded in the traps containing preservatives in the first experiment. Since the design of the traps was somewhat different in the two experiments, however (greater trap depth and the use of a funnel in the second experiment), it is possible that the capture efficiency of traps containing oil or detergent has been underestimated. As discussed earlier, live trapping

offers a number of advantages over conventional pitfall trapping, provided that it is possible to monitor traps frequently. The latter is an important caveat, since pitfall traps are typically used in large-scale studies for long-term monitoring of species diversity and relative abundance of arthropod fauna in different regions or habitats, where it is often not possible to monitor traps frequently and the use of preservatives becomes necessary. In studies involving larger arthropods in a narrow taxonomic category, such as field crickets, however, live trapping may be a viable alternative.

The estimates of relative abundance of species may also be more reliable with live trapping: the addition of chemicals may introduce strong biases in the capture probabilities of different taxa that may be attracted or repelled by these chemicals to different extents (Luff 1975). In our study, for example, ants and cockroaches were probably attracted by the scent of the oil, whereas spiders appeared to be attracted to detergent solutions.

In an extensive study that evaluated a number of sampling methods for insects in tropical forests, Gadagkar *et al.* (1990) found that whereas pitfall trapping was an effective method for hymenopterans, coleopterans, dipterans and hemipterans, capture rates for orthopterans were comparatively low. Our data also corroborate these results: the capture efficiency for ants and cockroaches was, on an average, higher than that for orthopterans, perhaps because orthopterans are generally less numerous than hymenopterans and dipterans. Inexplicably, few dipterans and coleopterans were captured in our study.

In the case of field and ground crickets, nymphal instars were trapped in significantly higher numbers than adults, in the leaf litter and tall grass microhabitats. This may be due to the higher density and smaller size of nymphs compared to adults, which would increase their probability of capture. In the short grass habitat, however, both nymphs and adults were captured at similar low rates, which may indicate that this is not a preferred habitat for either. Our empirical observations suggested, however, that the short grass was in fact a preferred habitat for the adults of at least four species of field crickets, two of which were never captured in the pitfall traps over the entire sampling period of 15 weeks.

In the grassy microhabitats, the mean abundance of field and ground crickets was much higher in the wet season than in the dry, reflecting a general increase in the abundance of both nymphs and adults, of a number of insect species during the monsoon. There were, however, no significant differences in mean abundance between the dry and wet seasons in the leaf litter microhabitat. This could be because the species inhabiting the grassy microhabitat are highly seasonal, with peak abundance during the monsoon, whereas those in the leaf litter habitat tend to occur throughout the year. The fact that 8 of the 15 species of crickets were trapped exclusively in grassy habitats during the wet season lends credence to this view.

The overall low capture rates of crickets in pitfall traps, however, precluded any meaningful quantitative analysis of relative abundance of species, both within and between microhabitats. The data shown in Table 1 were obtained after 15 weeks of sampling, and yet the numbers of crickets captured, particularly adults, were too low for statistical analysis of relative abundance at the species level. Other problems of pitfall trapping include the biases in trapping ability introduced by microhabitat structure, which could be different for different species (Melbourne 1997, 1999). This precludes the use of any general correction factor that could be applied to an entire taxon above the species level. As a result, the estimates of relative abundance of cricket species obtained from pitfall trap data are likely to be highly unreliable. In our experience, even species richness would be underestimated, since a number of cricket species that were found by *ad lib* acoustic and visual sampling did not appear in the pitfall traps. The efficiency of pitfall traps and the unreliability of the data obtained make it a poor method for a quantitative examination of ensiferan species richness and relative abundance. We believe that all-out acoustic and visual sampling may be more effective and reliable for the quantitative study of ensiferan species assemblages and our future efforts will be directed at examining and developing these techniques.

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